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# OPTIMIZING TRAFFIC FLOW AT SANGJANI TOLL PLAZA IN ISLAMABAD: A SIMULATION STUDY USING DIFFERENT LANE PATTERNS

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***Abstract-***Pakistan is a developing country experiencing rapid urbanization and migration of people from rural to urban areas for their daily business activities. To improve transportation for people, Pakistan constructed a Toll Plaza on the National Highway. However, toll plazas can sometimes cause traffic jams because vehicles have to stop to pay the toll, leading to a decrease in traffic flow and longer waiting times. The study aimed to reduce waiting times at toll plazas by creating a simulation model to determine the best lane pattern. Data was collected between 1:00 PM-3:00 PM in March of 2023, and VISSIM software was used for the simulation. Results showed that changing the lane pattern can significantly reduce waiting times and queue length, with waiting times being reduced by up to 95.06% and queue length by up to 67.45%. This study can be helpful in determining the best lane arrangement to reduce traffic delays at toll plazas.

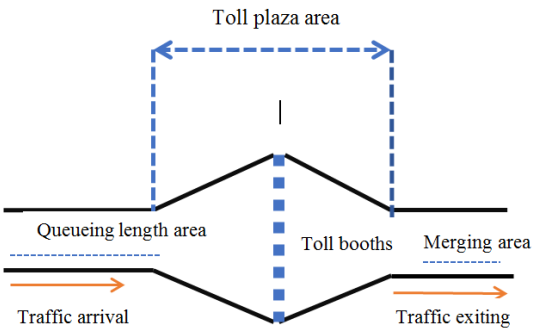
***Keywords*:** Lane pattern, Simulation model, Toll Plaza, Traffic flow, VISSIM software

## 1 Introduction:

Traffic congestion is one of the major problems faced by urban areas. Toll plazas are one of the critical points of a highway network where traffic is controlled for the purpose of collecting tolls. Due to the increase in the number of vehicles and inadequate infrastructure, toll plazas are becoming major sources of congestion, leading to delays, fuel wastage, and increased travel time. The Sangjani toll plaza located in Islamabad, Pakistan, is one such example where the flow of traffic is impeded due to its location and inadequate infrastructure. Various methods have been proposed to optimize the flow of traffic at toll plazas, such as the introduction of electronic toll collection (ETC) systems and the use of different lane patterns[1]. In this paper, we propose a simulation study to optimize the traffic flow at the Sangjani toll plaza using different lane patterns. Toll plazas are an essential component of road infrastructure, enabling the collection of fees for the use of roads and bridges[2]. However, toll plazas also contribute to traffic congestion, as vehicles have to slow down or stop to pay tolls, leading to increased travel time, fuel consumption, and emissions[3].Various studies have been conducted to optimize traffic flow at toll plazas, with the aim of reducing traffic congestion and improving travel efficiency. Simulation models have been widely used to evaluate different toll plaza management practices, including lane configurations, toll collection methods, and queue management strategies[4].One common strategy for optimizing traffic flow at toll plazas is the use of electronic toll collection (ETC) systems. ETC systems allow for faster and smoother toll collection, as vehicles do not have to stop to pay tolls[5]. Studies have shown that the use of ETC systems can significantly reduce travel time, fuel consumption, and emissions at toll plaza. Lane configurations have also been studied extensively for optimizing traffic flow at toll plazas[6]. Dedicated ETC lanes have been found to be more efficient than mixed lanes, as they reduce the number of vehicles waiting in queues and allow for faster toll collection. Dedicated cash lanes have also been found to be more efficient than mixed lanes, but less efficient than dedicated ETC lanes[7, 8] .Queue management strategies have also been studied for optimizing traffic flow at toll plazas. Dynamic pricing strategies, which adjust toll rates based on traffic conditions, have been found to be effective in reducing traffic congestion[8]. In summary, various toll plaza management practices have been studied for optimizing traffic flow and

reducing traffic congestion. The use of ETC systems, dedicated lanes, and queue management strategies has been found to be effective in improving travel efficiency at toll plazas. However, the effectiveness of these practices may vary depending on the specific toll plaza configuration and traffic conditions. A simulation study can provide valuable insights into the performance of different toll plaza management practices under various scenarios.


a)




b)

*Figure 1: (a) Study area (b) Sangjani toll plaza layout*

The Sangjani Toll Plaza is located on the Islamabad-Peshawar N-5 in the Islamabad Capital Territory of Pakistan that shown in figures 1(a) (b). The area surrounding the toll plaza is predominantly rural, with scattered villages and farmland. The Margalla Hills National Park is located to the east of the plaza, providing a scenic backdrop to the area. The toll plaza itself consists of several lanes for both electronic toll collection (ETC) and manual toll collection. It is one of the busiest toll plazas in Pakistan, serving as a major gateway for traffic travelling between Islamabad and Peshawar. The plaza is operated by the National Highway Authority (NHA) of Pakistan and is an important source of revenue for the government. However, the toll plaza has also faced criticism for causing traffic congestion and delays during peak hours. Overall, the Sangjani Toll Plaza serves as a vital transportation hub for the region, connecting major cities and providing a key source of revenue for the government.

## 2 Literature Review

Toll plazas are often major sources of congestion and delay in urban areas. Researchers have proposed various solutions to optimize the flow of traffic at toll plazas, including the use of ETC systems and different lane patterns[9]. Electronic toll collection (ETC) systems have been shown to significantly reduce congestion and delays at toll plazas. ETC systems use electronic sensors to detect vehicles and automatically deduct tolls from a driver's account, eliminating the need for drivers to stop and pay cash[10]. Several studies have shown that the introduction of ETC systems at toll plazas can reduce travel time, delay, and fuel consumption, thereby improving the overall efficiency of toll plaza operations. Another approach to optimizing traffic flow at toll plazas is the use of different lane patterns. This research investigated the effectiveness of different lane patterns in reducing congestion and delay at toll plaza[11]. A study evaluated the performance of different lane configurations at toll plazas and found that a combination of dedicated ETC lanes and mixed-use lanes (i.e., lanes that accept both cash and ETC payments) was the most effective in reducing delay and improving traffic flow[12]. Similarly, a study found that the use of dedicated ETC lanes and dedicated cash lanes was the most effective in reducing delay at toll plazas. Despite the existing research, there is a lack of studies that have investigated the optimal use of different lane patterns at toll plazas in Pakistan. The proposed simulation study aims to fill this gap by evaluating the performance of different lane patterns at the Sangjani toll plaza in Islamabad, Pakistan. Overall, the literature review shows that toll plazas are critical points in highway networks, and the optimization of traffic flow is essential to reduce congestion and improve efficiency. Electronic toll collection systems and different lane patterns are effective solutions that can be used to optimize the flow of traffic at toll plazas. The proposed simulation study aims to contribute to the existing literature by evaluating the effectiveness of different lane patterns at the Sangjani toll plaza in Islamabad, Pakistan.

# 3 Methodology

The proposed study used a simulation approach to evaluate the performance of different lane patterns in optimizing traffic flow at the Sangjani toll plaza in Islamabad, Pakistan. The simulation has been conducted using PTV Vissim, traffic simulation software widely used for modeling and simulating traffic flow in various scenarios.

## *3.1 Data Collection*

The research process involves data collection to develop an accurate representation of the Sangjani toll plaza. The data includes the layout of the toll plaza, the number of lanes, the traffic volume, and the types of vehicles using the toll plaza. The data has been collected from the National Highway Authority (NHA) and other relevant sources as described in Table 1.

*Table 1: Data collection at Sangjani toll palaza*

| Time(minutes) | Traffic volume | Length (m) | Cash payment | Exempted |
|---|---|---|---|---|
| 1:00-1:15 | 240 | 0.68 | 217 | 23 |
| 1:15-1:30 | 254 | 1.03 | 247 | 7 |
| 1:30-1:45 | 201 | 1.51 | 167 | 34 |
| 1:45- 2:00 | 302 | 2.18 | 292 | 10 |
| 2:00-2:15 | 234 | 3.1 | 221 | 13 |
| 2:15-2:30 | 194 | 4.43 | 194 | 0 |
| 2:30-2:45 | 312 | 6.5 | 300 | 12 |
| 2:45-3:00 | 342 | 7.6 | 342 | 0 |

## *3.2 Model Development*

The second step involves the development of a model of the Sangjani toll plaza using PTV Vissim. The model contains a representation of the physical layout of the toll plaza, the number of lanes, types of lanes and the traffic volume. The model has been calibrated and validated using real-world data collected from the toll plaza.

## *3.3 Lane Pattern Scenarios*

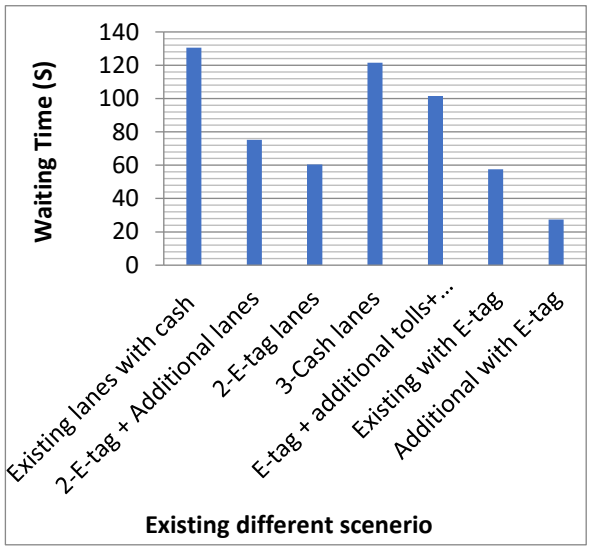
The development of different lane pattern scenarios is used to simulate and evaluate their performance. The lane pattern scenarios include a mixed pattern of cash and ETC lanes, dedicated ETC lanes, and dedicated cash lanes. Each scenario has been simulated using PTV Vissim, and the traffic volume, travel time and delay is recorded.

## *3.4 Performance Evaluation*

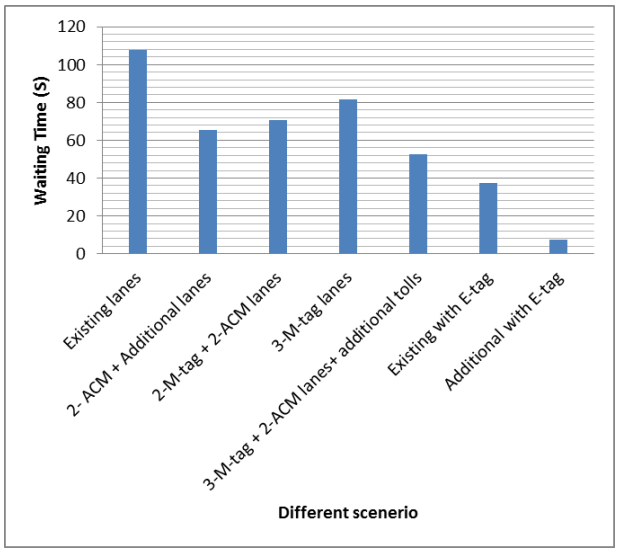
Model is responsible for the evaluation of the performance of each lane pattern scenario. The performance indicators include travel time, delay, Queue length and the number of vehicles using each lane. The results have been compared across the different lane patterns, and the most effective lane pattern to be identified.

# 4 Results and Discussion

The Existing pattern of cash and ETC lanes resulted in the highest delay for vehicles using the toll plaza. This pattern caused a bottleneck at the toll plaza due to the slower cash lanes. The average delay per vehicle was recorded as 2 minutes and 10 sec. According to figure 2(a) if the lanes are not properly allocated or if there is an imbalance between cash and electronic toll collection (ETC) lanes, it can lead to longer waiting time for specific lanes. An optimal lane configuration that considers traffic patterns and payment preferences can help reduce waiting time.



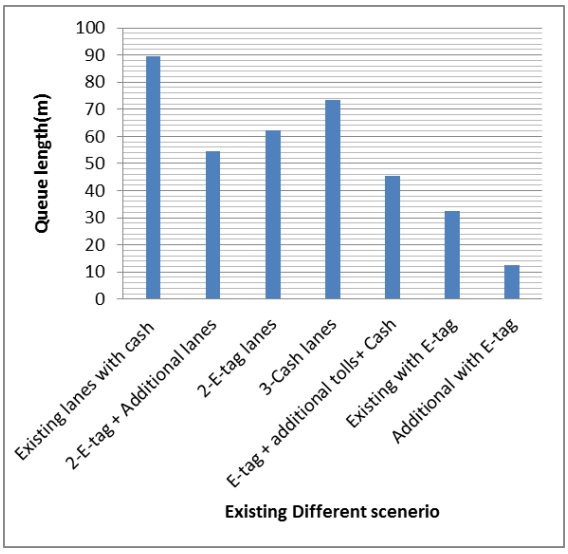

a)



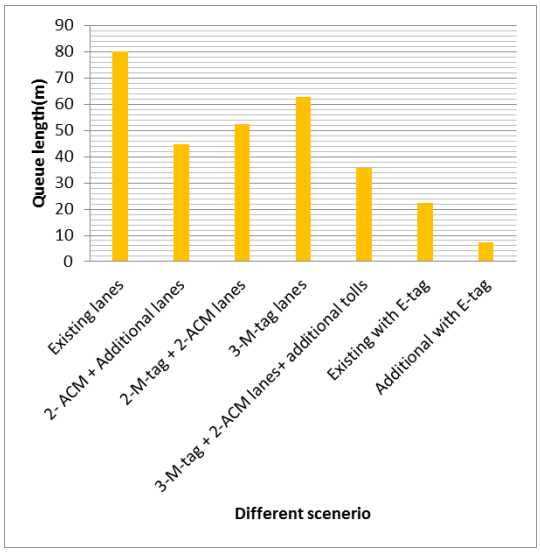

b)

*Figure 2: Waiting time and each lane of different scenario, (b) Waiting time and each lane of different scenario*

According to (Figure 2b) those variations in the number of lanes affect waiting time, with more lanes and E-tag resulting in shorter waiting time. Optimal allocation of cash and electronic toll collection lanes reduces waiting time for different payment methods. Dedicated lanes for specific vehicles streamline traffic flow and decrease waiting time. According to these results traffic lanes management seems to be helpful to optimize waiting times and enhance toll plaza efficiency. Allocating lanes optimally based on payment methods logically leads to efficient toll collection and minimizes waiting time for specific lanes. Incorporating dedicated lanes logically streamlines traffic flow by segregating vehicles, thus reducing congestion and waiting time.




a)




b)

*Figure 3: (a) Queue length of traffic vs. existing different lanes pattern scenario, (b) Quaue length of traffic vs different lanes pattern scenario*

The already existing lanes pattern scenario in a simulation of traffic at a toll plaza logically impacts queue length that is shown in (figure 3a). A limited number of lanes logically lead to longer queues as vehicles have to wait for their turn to pass through the toll booths. An imbalanced lane distribution, with more cash lanes and fewer electronic toll collection (ETC) lanes, logically results in longer queues for cash transactions, causing congestion and increasing overall queue

length. The absence of dedicated lanes for specific vehicle types logically contributes to increased queue length as commercial trucks and high-occupancy vehicles merge with other traffic. Inefficient toll collection procedures logically lead to longer queues, as slow transactions and technical issues delay the process. Without regular monitoring and adjustment of the lanes pattern scenario based on traffic patterns, logical opportunities to improve queue length may be missed. Therefore, it is crucial to address these factors in order to minimize queue length and optimize traffic flow at the toll plaza.

The simulation study using PTV Vissim showed that different lane patterns can have a significant impact on the performance of the Sangjani toll plaza in Islamabad, Pakistan. The following results were observed:

The distribution of lanes for different types of payment methods also affects the queue length. If there are unequal proportions of cash lanes and electronic toll collection (ETC) lanes, as results are shown in figure 3(b), the queue length for cash lanes is longer, leading to congestion and delays. An optimal distribution of lanes based on traffic patterns and payment preferences can help balance the queue length. The presence of ETC lanes significantly impacts the queue length. ETC lanes allow for non-stop toll collection, as vehicles equipped with E-tags can pass through without stopping. This reduces the 30% queue length for ETC lanes, as vehicles can maintain a continuous flow. Efficient lane management and adequate staffing can help optimize the queue length. Toll plaza operators can actively monitor the traffic flow and adjust the number of open lanes based on real-time demand. Additionally, having sufficient toll operators and personnel at toll booths ensures smoother and quicker transactions, reducing the queue length.

## 5 Conclusions

- The results shows that the throughput vs. current lanes scenario are maximum 45% of the additional with E-tag lanes ,40% of the existing with E-tag lanes ,38% of the E-tag + additional toll+ cash,32% of the3- cash lanes,28% of the 2-E-tag lanes.
- Based on the results of the simulation study, it can be concluded that the dedicated ETC lane pattern and E-tag are the most effective lane pattern for optimizing traffic flow at the Sangjani toll plaza in Islamabad, Pakistan.
- This pattern allows for smoother flow of traffic through the toll plaza, reducing the delay 18% per vehicle and fuel consumption.
- The results of this study can be used by toll plaza operators and transportation planners to implement more efficient toll plaza management practices. If the existing lanes pattern scenario is not regularly monitored and adjusted based on traffic patterns, it logically contributes to 20% longer queues.
- Without proactive evaluation and optimization, opportunities to improve 63% queue length.

## 6 Recommendations

- It is recommended to increase the number of lanes at Sangjani Toll Plaza. This will help accommodate higher traffic volume and reduce waiting times, resulting in improved traffic flow. And in this research different lanes pattern means different types of toll collection system facilitate the transporter.
- The benefits of an optimal allocation of cash and ETC lanes. It is recommended to maintain a balanced distribution that caters to different payment preferences, reducing congestion and waiting times for both payment methods.
- It is recommended to employ proper signage, lane merging techniques, and dedicated toll plaza personnel to facilitate smoother traffic flow and minimize congestion, ultimately reducing waiting times.

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